DIMENSIONS NBS

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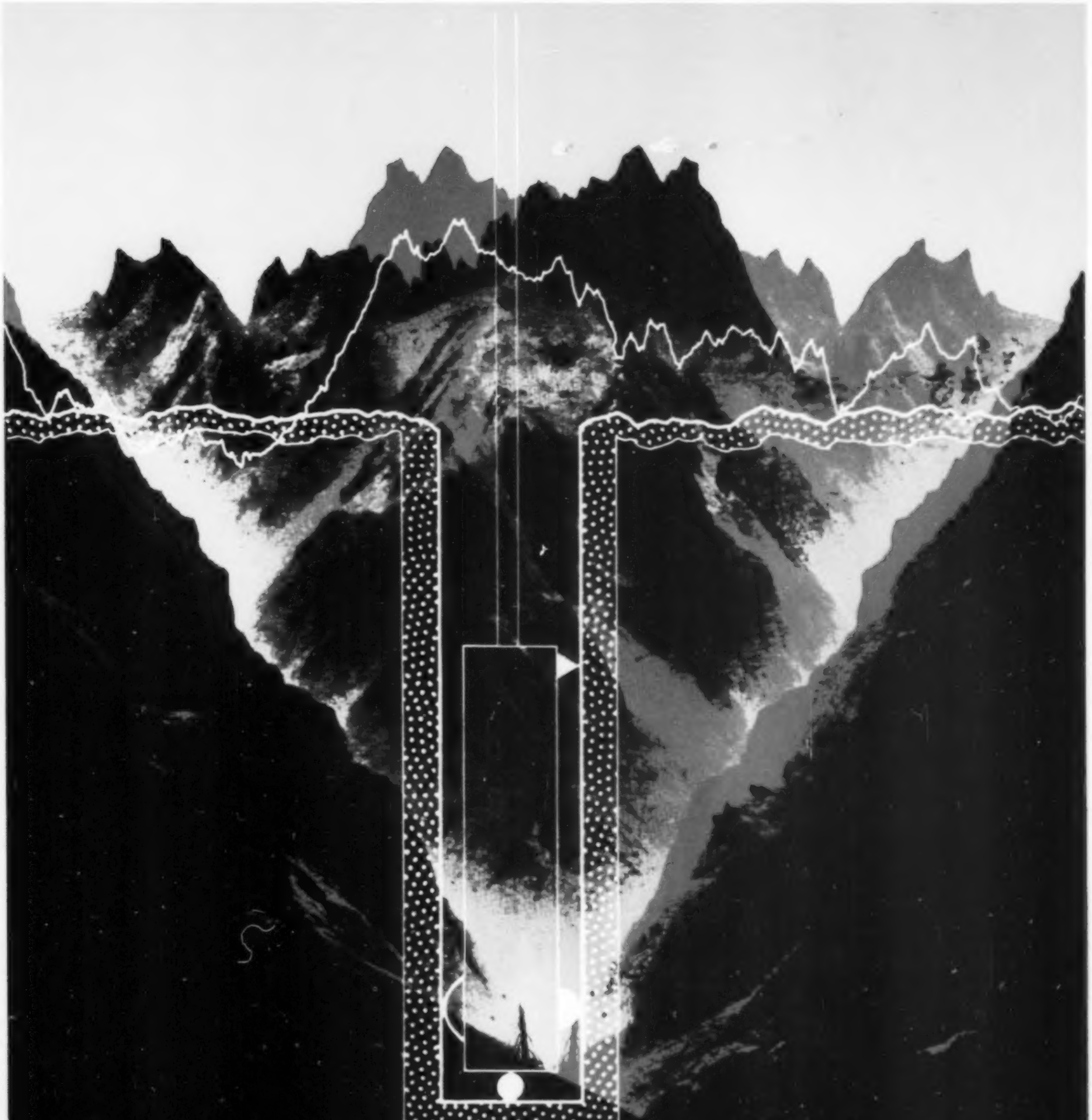

SWINGING TO THE EARTH'S TILT. See page 2.

COMMENT

PRECISION MEASUREMENT AND FUNDAMENTAL CONSTANTS

Precision measurement and the accurate determination of the fundamental constants of nature, such as the speed of light in vacuum (c), are essential to the development of all science and technology. First, precise measurements andreliable values of the constants are required for a critical comparison of the basic theories of physics with experiment, thereby advancing our understanding of the physical world.

Second, determining the "next decimal place" is never trivial. It requires the development of new, state-of-the-art methods which invariably have wide application. Recent examples at NBS include: the determining of c by directly measuring the frequency of laser radiation, which will soon lead to redefinition of the meter; defining and maintaining the U.S. legal volt in terms of the fundamental constant ratio $2e/h$, as determined using the ac Josephson effect in superconductors (e is the elementary charge, h is the Planck constant); determining the Avogadro constant by directly measuring in meters the lattice spacing of pure silicon crystals, using combined X-ray and optical interferometry, thereby extending the length scale to the picometer region; and determining the gyromagnetic ratio of the proton, thus yielding a highly accurate value of the fine-structure constant, which in turn allows the unequivocal comparison of quantum electrodynamic theory with experiment.

Third, the fundamental constants of nature are the obvious keys to the development of an everywhere-reproducible and invariant system of measurement units, one of the major goals of the science of measurement (metrology).

Since its founding in 1901, NBS has had a strong, inhouse program in the precision measurement-fundamental constants (PMFC) field as part of its responsibility for the National Measurement System. However, NBS has long been aware that the PMFC field is too vast for it to pursue all available opportunities alone, and that a great deal of talent exists in the academic community for research in the PMFC field. Recognizing that a grants program would be an efficient way of tapping this reservoir of talent, NBS began in 1970 to award Precision Measurement Grants to scientists in academic institutions for experimental work in precision measurement areas important to metrology. The grants promote and encourage fundamental research in these areas in the colleges and universities, and foster contacts between NBS scientists and those researchers in the academic community who are actively engaged in such work. One of the aims of the NBS Precision Measurement Grants program is to make it possible for scientists in academic institutions to pursue new, innovative ideas in the PMFC field for which other funding may be difficult to find. An article on the two grants most recently awarded appears in this issue of DIMENSIONS/NBS.

Yet another facet of NBS work in the PMFC field is its Fundamental Constants Data Center, supported in part by the NBS Office of Standard Reference Data and in part by the Bureau's Center for Absolute Physical Quantities. One of the purposes of the Data Center is to provide a centralized source of information on the fundamental constants and closely related precision measurements. It publishes a newsletter, *Preprints on Precision Measurement and Fundamental Constants*, which lists preprints and reprints on relevant current research and responds to numerous inquiries, such as advising scientists on the potential importance of a fundamental constant experiment they propose to undertake or providing values of various physical and numerical constants for other data compilations.

Of equal importance to the Data Center's information activities is its participation in the periodic development of sets of "best" values of the constants by means of least-squares adjustments. The most recent adjustment was carried out in 1973 by the Data Center in collaboration with the Committee on Data for Science and Technology (CODATA). In preparation, NBS cosponsored and hosted, in August 1970, an international conference on PMFC.

Since the completion of the 1973 adjustment and subsequent adoption of the resulting set of recommended constants by CODATA for international use, a number of new experiments and theoretical calculations have been completed, yielding significantly improved values for several constants. As a result, work is now underway to carry out a new adjustment in collaboration with CODATA. A preparatory conference in June 1981, similar to the 1970 meeting and entitled "Second International Conference on Precision Measurement and Fundamental Constants," will again provide an international forum for scientists actively engaged in PMFC research and in the testing of related theory. It is expected that new results reported at the Conference will be included in the new least-squares adjustment. The latter should be completed by the end of 1981 and the resulting set of recommended values officially adopted by CODATA for international use early in 1982.

The motivation for the Bureau's extensive efforts in the PMFC field, as briefly summarized here, can perhaps be conveyed best by the following quotation from F.K. Richtmyer, a famous American physicist of the early 1900's: "Why should one wish to make measurements with ever-increasing precision? Because the whole history of physics proves that a new discovery is quite likely to be found lurking in the next decimal place."

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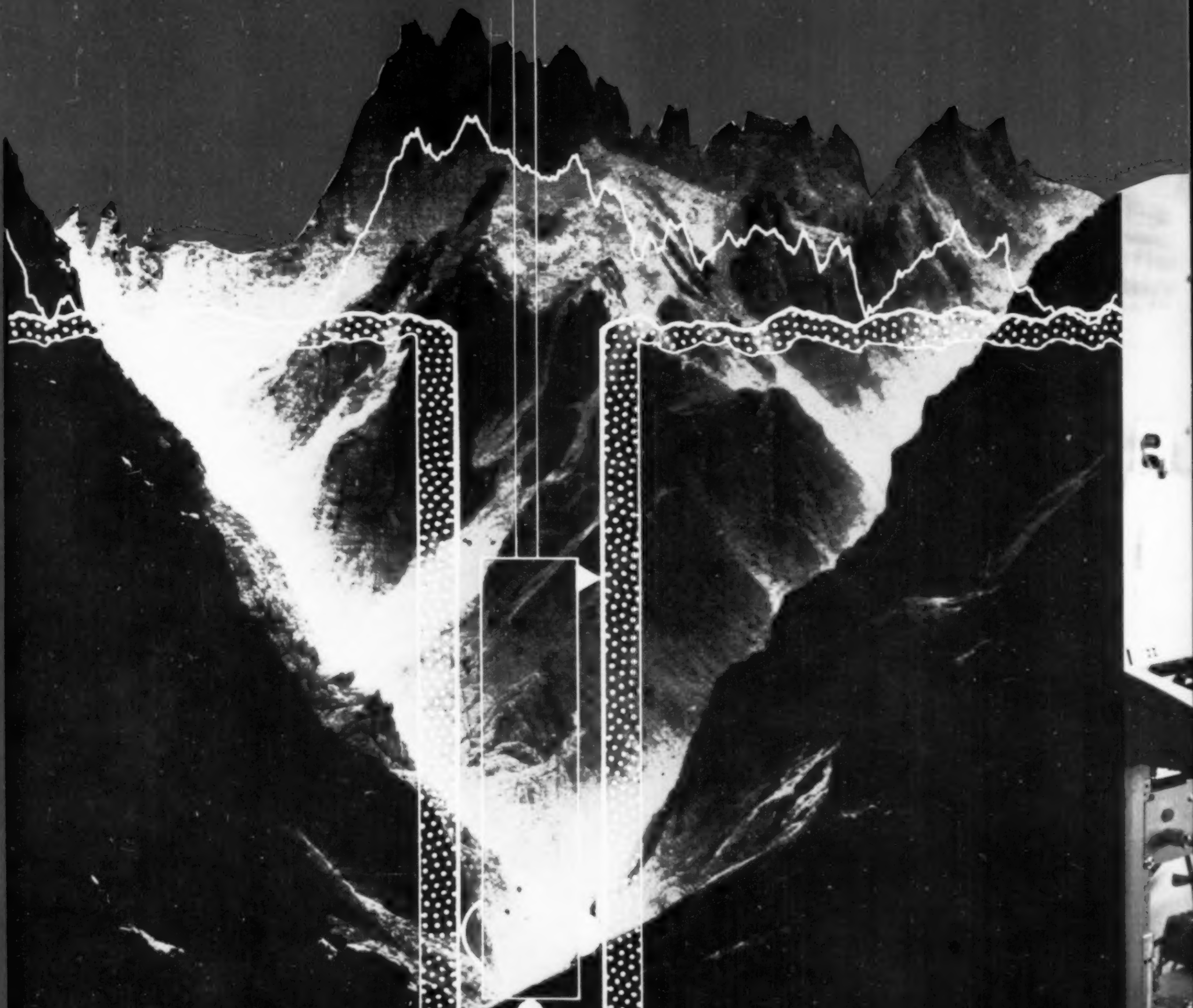

RTH'S TILT

by Fred McGehan

COVER STORY

NBS physicist Judah Levine examines a wiring diagram of a microcomputer used to obtain data from buried tiltmeters designed to detect the slightest tilt in the earth's surface.

A long, plain white trailer stretches out on flat prairie land with a view of the snow-capped Colorado Rockies to the west as a backdrop. Inside the trailer, amid a welter of equipment left over from previous projects, a microcomputer receives data every 6 minutes. At 3 minutes past each hour, the microcomputer relays an hour's collection of data over a radio hookup to a large computer in Boulder, some 32 kilometers (20 miles) away.

Twenty-four hours a day, 7 days a week, this electronic apparatus provides a mound of data that may lead to more accurate prediction of earthquakes.

That microcomputer, you see, is connected by land lines to two tiltmeters—highly sensitive devices designed to measure the slightest tilt in the earth's surface—buried 30 meters (100 feet) beneath the Colorado prairie. Judah Levine, a physicist with the National Bureau of Standards, is directing the research, which is sponsored by the University of Colorado and the U.S. Air Force Geophysical Laboratories.

Although tiltmeters have been used experimentally for a number of years as early-warning predictors along the San Andreas fault in California, their usefulness has been questioned on at least two grounds. First, there is the problem of obtaining agreement between measurements from any two meters in the same area; the second problem is that of understanding or interpreting the readings, once obtained. In many instances, the meters in operation were designed originally to guide rockets and not to detect earthquakes.

Levine explains the first problem: "You take 2 meters, put them a few feet apart, and look at measurements of long-term tilt. You get very little coherence between the two instruments. Even within a week's time you get very different readings. This has plagued the business for a long time."

There are three types of tiltmeters—a vertical pendulum, a horizontal pendulum, and a straight line level. The vertical pendulum measures the position of the bob with respect to the case that encloses it; the horizontal pendulum resembles a garden gate and measures the swing of the gate as the post is tilted; and the straight line level resembles a ball on a track—if the track tilts, the

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ball rolls to one edge. Both the horizontal pendulum and the straight line level are difficult to build so as to obtain the high degree of stability needed for earthquake prediction.

Levine chose to construct the vertical pendulum tiltmeter; it is the simplest mechanically, but requires the most sophisticated electronic package to capture the data. With it, he says, "we're measuring the tilt of the local piece of ground with respect to the acceleration of gravity."

A half dozen vertical pendulum tiltmeters constructed by Levine have been located at two sites—the prairie east of Boulder and a slope of ground just to the west of the Bureau's laboratories in Boulder. At each site, well drillers sank 30-meter holes and lined them with 15-cm diameter well casings. The pendulums are suspended in a 2-m length capsule at the bottom of the steel casings along with the electronic packages for data transmission.

In explaining the working of his tiltmeters, Levine envisions a pendulum suspended on a string from a street light. "Gravity pulls the mass of the pendulum down and the string points along the direction of the acceleration of gravity," he says. The pole on which the street light rests represents the earth—the pole is perpendicular to the earth. Tilt is observed by continuously measuring the angle between the string and the pole. If the earth tilts, the angle will change. In Levine's tiltmeter system, the capsule in the pipe casing is the equivalent of the light pole.

In the best of all possible situations, the tiltmeter would measure only the tilt of the earth caused by the movement of the earth's crust prior to an earthquake. But it is not possible for the tiltmeter to be selective, and that is where the second problem comes in. How do you distinguish between movements caused by earthquake precursors and those caused by a variety of other natural phenomena, including earth tides, soil subsidence, ground water, and alternate freezing and thawing of the ground?

With the earth tide effect, for example, the angle between the pendulum and casing would change by about a 50th of a second of arc each day. This is due to the gravitational pull of the moon as it moves through its orbit and influences the pendulum; it is also caused by the earth being pulled toward the moon by gravitational attraction.

The ability to interpret the tiltmeter readings requires detailed knowledge of both the local area and the natural forces at work. It also requires considerable experience in measuring tilt at a particular location so that a pattern of naturally-occurring tilts can be established. Sudden, unusual tilt readings during the spring, for example, may be due to subsidence caused by heavy spring rains rather than by the shifting of rock layers deep within the earth. "There should be an annual cycle to this type of phenomenon," Levine notes.

And then there are the unusual readings that can be attributed to the measurement equipment itself. Shortly after setting up his tiltmeters at the prairie site, Levine noticed tilt changes that occurred only on sunny days. He eventually traced this to heating of the cables that brought the signals from the holes to the microcomputer in the trailer. "You have to establish a baseline of expected phenomena and then look for the unexpected," Levine stresses.

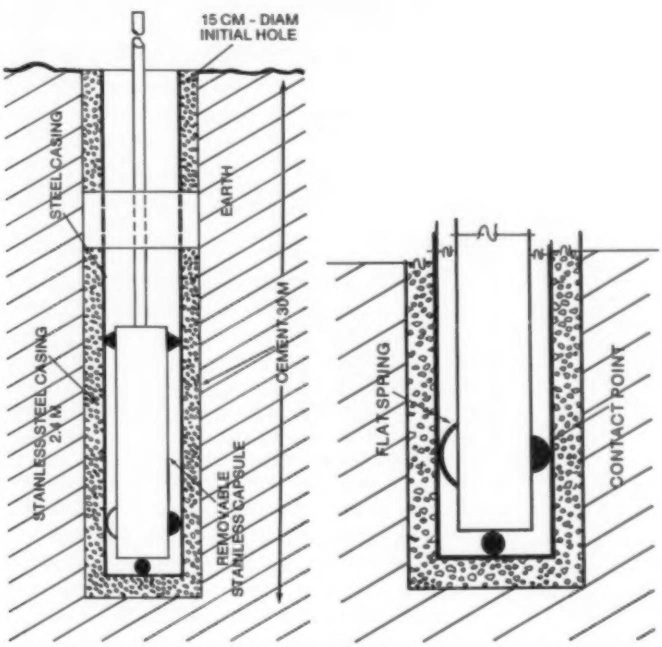
Although his tiltmeters have not been in place long enough to determine that baseline precisely (at least a year is required), Levine has found "reasonably good" agreement in measurements among the various tiltmeters at a single location. He terms this coherence "a major milestone."

The next step will be to move the tiltmeters from the seismically-inactive Boulder area to locations of known seismic activity. This summer, Levine expects to take his apparatus to Yellowstone National Park to study the elasticity of magma (molten rock) beneath the surface in some areas of the park. "One way to tell what's going on (beneath the surface) is to measure the response of the materials to the earth tides, a known excitation," Levine says. He will sink a series of tiltmeters into the ground and collect the data in Boulder, either by telephone or radio hookup.

Subsequently he hopes to install his tiltmeters along the Wasatch Fault near Salt Lake City, Utah. The meters would be in place for at least a year to measure long-term tilt. Levine says that the Wasatch area is "interesting because it has been active in the past, but not in the recent past." The last very large earthquake along the fault was several hundred years ago, although smaller earthquakes (magnitude 3 or less on the Richter scale) are quite common.

Work by seismologists at the University of Utah suggests that stress may be building along the fault in the general vicinity of Ogden, Utah, and that this stress accumulation may be enough to cause an earthquake in the foreseeable future. Levine

On a tiltmeter testing site near Erie, Colo., Levine troubleshoots an electrical problem with one of the tiltmeters buried 30 meters beneath this prairie land. A microcomputer, housed in a trailer in the background, takes data from the tiltmeters and sends it to the laboratory in Boulder.



Schematic drawing of the 30-meter-deep borehole used to house the tiltmeter.

would install his instruments in the Ogden area in an attempt to measure the changes in the local tilt that may accompany the increasing stress. These tilt measurements would then be combined with the seismic and geodetic measurements collected by others to improve understanding of the fault motion and yield a better estimate of the seismic risk. □

EARTHQUAKE PREDICTION

In the world of earthquake prediction, the tiltmeter is just one of several instruments available to the geophysicist. Many other methods and instruments are brought into play to evaluate the risk of an impending quake.

While the tiltmeter will give perhaps the earliest indication of a sudden shift of subterranean rock, this of itself is not enough to justify a warning. As noted in the accompanying article, the sudden tilt could be caused by a local anomaly or by a malfunction of the equipment. The tilt reading must be corroborated by other evidence.

Seismographs and magnetometers are two other instruments often used in an earthquake monitoring network. Seismograph arrays can detect changes in the velocity of seismic waves (caused by other earthquakes) passing through a region experiencing stress; magnetometers detect changes in the magnetic field in the region. Other signs to look for include: sudden changes in level, turbidity, and temperature of deep-well water; an increase in the level of radon gas in well water; and changes in the electrical resistivity of the earth. When these data mesh, then the probability of a local earthquake is quite high. Just when that earthquake will occur, however, usually cannot be predicted to the day or even the week. Much more research is needed to fine-tune earthquake monitoring systems.

Testing For Technical Competence

The National Voluntary Laboratory Accreditation Program

by Emily B. Rudin

In this era of enlightened consumerism, testing products before they are marketed has a high priority. Purchasers want to be assured that items will do what manufacturers say they will. Likewise, manufacturers want to be confident that their products will perform according to overall designs and objectives. And on an international scale, well-made products can help strengthen America's industrial vitality in the global marketplace.

To test the quality of thousands of different products, between 10 000 and 20 000 private laboratories have swung into operation; 10 years ago, only a portion of these existed. Reflecting this steady increase in laboratories has been the birth of over 70 systems for assessing their technical competence in carrying out specific tests. Thirty years ago, there were just a half dozen such accreditation systems.

The National Bureau of Standards (NBS) provides the technical arm of an active, growing program that can streamline the accreditation process: the National Voluntary Laboratory Accreditation Program, or NVLAP (pronounced nav' lap). Says Margaret Federline, a NVLAP project leader in the NBS Office of Testing Laboratory Evaluation Technology (OTLET): "We expect that the need for laboratory accreditation will increase with the technological complexity of products and consumers' growing demands for goods and services that meet standards for interchangeability, durability, safety, and quality."

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NVLAP's role in helping laboratories improve their measurement capabilities and standards is in line with the Bureau's basic mission—to establish and maintain national standards of measurement and to provide methods for making measurements consistent with those standards.

NVLAP: Fulfilling a Need

While conventional laboratory accreditation is beneficial from many viewpoints, there have been some problems.

The frequency of assessment and specificity of many accreditation programs can create an economic burden for the laboratories as well as for the manufacturers—and, ultimately, for consumers. A laboratory may perform a number of different tests for a single product. These tests are designed to assess the product's adequacy on behalf of various special-interest parties, such as manufacturers, Federal and State regulatory agencies, or insurance companies. Each of those parties has an interest in assuring itself that the laboratory is qualified to perform the tests. Thus, representatives of some of these groups may spend up to several days inspecting a testing laboratory, often interrupting normal operations. For the laboratory, this means that special support staff must be hired primarily to prepare for and host these outside inspectors.

NVLAP project leader Diana Kirkpatrick and engineering technician Thomas Prather measure the distance burned in a radiant panel test for flammability of loose-fill cellulosic insulation.

For example, thermal insulation materials must be tested to meet a number of different standards or specifications. Consider those set by Federal agencies alone. The Consumer Product Safety Commission requires cellulosic insulation to meet flammability and corrosiveness standards. Labeling requirements of the Federal Trade Commission must be met. The Department of Energy has standards requiring testing for flammability, R-value, density, fungal growth, odor, and corrosiveness. Finally, the insulation must satisfy procurement requirements for Government use set by the Department of Housing and Urban Development, the General Services Administration, and State and local authorities. It is clear that duplicating evaluation efforts can involve extra expenditures of time and resources.

Here, then, is the multiple challenge that confronted the Department of Commerce in 1976. Basing its solution on an NBS study and extensive public hearings, DOC responded to what it perceived was a need for a coordinated national accreditation system by establishing NVLAP.

What Is NVLAP?

NVLAP is a voluntary national system designed to recognize laboratories' competence in conducting specific tests or types of tests. Because this system is useful for a wide range of products and services, an "umbrella" effect is created by a uniform approach to the laboratory assessment process. This relieves some of the overlap and specificity of single-purpose accreditation. In the case of thermal insulation, several of the regional and local accreditation programs have been voluntarily phased out in favor of NVLAP accreditation.

NVLAP project leaders Jeffrey Horlick and Kirkpatrick select carpet proficiency test samples.

Thomas Hobbs, chief of health physics in the Occupational Health and Safety Division, takes a reading of a thermoluminescent radiation detector for personnel dosimeters. Observing the procedure is Margaret Federline, project leader of a LAP for processors of personnel dosimeters.

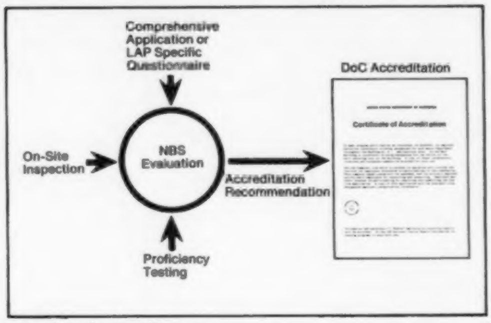
NVLAP's overall operation is managed by the DOC Office of Product Standards Policy, which makes major decisions about NVLAP policy and grants accreditation to laboratories on behalf of the Secretary of Commerce. Responsibility for performing the technical evaluation of laboratories lies with NBS in OTLET (part of the Office of Engineering Standards).

There are currently three laboratory accreditation programs (LAP's) administered by NVLAP: thermal insulation, carpet, and freshly mixed concrete. A number of other LAP's have been proposed and are in various stages of development. Product and service areas covered by these new programs include testing services for acoustical materials, electromagnetic calibration, woodburning fuel appliances, athletic headgear, and processing of personnel dosimeters.

How NVLAP Works

Anyone—a private citizen or group, non-profit organization, or Government agency—can ask that DOC develop a LAP in a given product area. The requestor must identify the product, standards, test methods, and market potentially affected, and substantiate all claims about how the LAP will benefit the public and why Government involvement is needed. DOC then publishes a proposed determination of need in the *Federal Register* and asks for public comment. (This step is omitted when a Federal agency requests a LAP, since each agency is responsible for establishing evidence of need in developing its own programs.)

If the public substantially supports the proposal, DOC proceeds to the next stage, which involves



NVLAP Evaluation Process.

soliciting advice on accreditation criteria from all representative organizations that the proposed LAP might affect. Such groups might include consumers, product manufacturers, the wholesale industry, and the testing community. "One great asset of NVLAP is that there are a lot of opportunities for contributions from all sides," says Gerald A. Berman, leader of OTLET's Laboratory Performance Group.

The NVLAP staff evaluates recommendations for criteria, and then publishes general and specific accreditation criteria in the *Federal Register* for public comment. DOC analyzes all contributions and incorporates those deemed suitable for accreditation criteria. The last step is the publication of all general and specific criteria that testing laboratories must meet to be accredited by NVLAP for a particular product or service. Based on this procedure, DOC establishes a LAP.

The final criteria for a particular LAP reflect the most advanced technology in laboratory operation and management, and are sufficiently flexible to accommodate diverse testing methods. Evaluations are based on general criteria, such as organizational structure, technical management, professional and ethical conduct, and quality-assurance procedures in the laboratory. In addition, the laboratory is judged against specific criteria, which cover test methods for personnel competence, facilities and equipment, test plans, calibration and data-handling procedures, record-keeping, and quality-control checks and audits. These criteria apply to all test methods in any LAP without requiring changes whenever a test method is added or revised.

Before evaluation, an applicant laboratory is given supplemental information detailing how the criteria are to be integrated and implemented for each test method. Together, the criteria and supplementary information establish a framework for an opera-

tional model of a laboratory on which the uniform evaluation of laboratories can be based—regardless of the testing or service area.

NVLAP's function is based on several key elements:

- Uniform yet thorough criteria for broad areas of laboratory evaluation are designed to alleviate economic burdens and save time for the testing community.
- Optimal frequency of site visits helps reduce interference with normal laboratory operations.
- Accreditation carries the international recognition traditionally associated with a Federal program.
- Participation is voluntary. "We don't advertise or regulate," Federline explains. "Instead, NVLAP provides an independent way for a laboratory to improve quality assurance, either to help it comply with Government regulations or simply to satisfy the laboratory's own desire to upgrade its standards of operation."
- Laboratories are evaluated only by those with direct experience in laboratory methodology and management. "Being assessed by equals," Federline says, "helps laboratories build a strong and positive rapport with NVLAP."

Based on careful selection of nonpartisan, qualified professionals with extensive experience in laboratory management and methodology, the peer-review system combines several examination techniques found to determine comprehensively a laboratory's ability to perform specific tests. Before assessors make an actual visit, laboratories must complete short questionnaires and application materials to provide detailed information about the laboratory's operations and procedures. Next, proficiency samples for selected test methods are submitted to the applicant laboratory for testing, to flag any potential trouble spots. Finally, assessors visit the laboratory to verify previous written information and test results. A major goal of the on-site survey is to determine by uniform, objective evaluation how closely a laboratory conforms with criteria during its normal operations.

NVLAP emphasizes a positive approach. "We're here to help people; we're not failure-oriented," Federline says. "The program's purpose is to accredit competent laboratories, not to deny them accreditation." NVLAP's structure calls for extensive feedback procedures. Each laboratory that does not meet an accreditation program's criteria is informed in detail as to what aspects are unsatisfactory and is given ample time to correct them.

Rick Seifarth (left), an NBS Cement and Concrete Reference Laboratory inspector, and Bob Gladhill, a NVLAP project leader for the concrete LAP, verify the dimensional stability of two concrete cylinder molds.

Douglas Thomas, project leader for the proposed athletic equipment LAP, inspects a monorail system used to measure the impact resistance of football helmets.

Future Directions

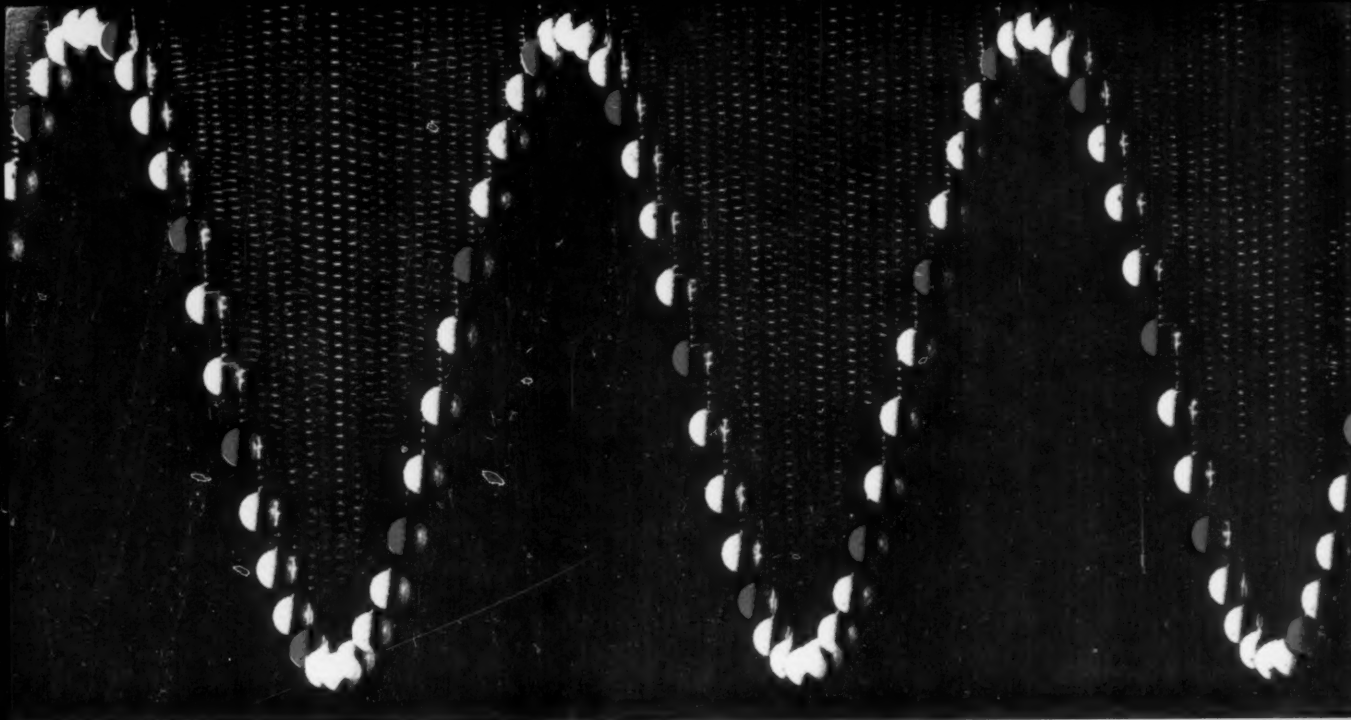
According to Berman, NVLAP's practical success has led some State accreditation programs to begin referring to NVLAP in certain testing areas such as thermal insulation. "This trend should continue," he says, "as NVLAP matures and diversifies in products and services."

Does this mean an uncertain future for existing accreditation systems? Not at all, according to Federline. "We're not looking to replace these systems," she explains. "In regions or States where some accreditation systems don't exist, NVLAP can be helpful in meeting the need for accreditation programs."

In areas where programs do exist, NVLAP can exchange resources and expertise. This has already begun to happen, as Berman mentions. In such a case, an independent accreditor can choose to accept NVLAP's criteria for a product testing area in lieu of its own. It can then arrange to accredit a laboratory automatically if that laboratory has already been accredited by NVLAP.

Still a future possibility is the opposite case. NVLAP may some day arrange to accredit a laboratory simply on the basis of independent accreditation systems already active in a testing field. Here, Federline speculates, inspectors would probably have to be trained in NVLAP methodology, and there would naturally need to be a consensus on uniform criteria to be used in the accreditation process.

In a time when efficiency has never been more important, NVLAP can be of great value in streamlining the accreditation process by helping all participants—laboratories, accreditors, manufacturers, consumers, and local governments—avoid overlapping efforts and direct their energies to a mutually beneficial goal of reliable laboratory testing. □



PHYSICS AT THE MEASUREMENT LIMITS

by Michael Baum

With the awarding this past fall of Precision Measurement Grants to Professors William Oelfke of the University of Central Florida and William Wing of the University of Arizona, the NBS Precision Measurement Grants Program began its second decade.

Since 1970, NBS has used the Precision Measurement Grants Program to help fund a wide variety of research projects at colleges and universities all over the country. The projects tend to be quite disparate, the common bond being that the researchers plan to measure something very carefully in the physical sciences. Oelfke's project, for example, is entitled, "Quantum Limited Measurements of a Harmonic Oscillator," and Wing's, "Electrostatic Trapping of Neutral Atomic Particles."

Past grants have been awarded for such projects as the construction of a nearly frictionless rotating cylinder, a cryogenic device for determining the

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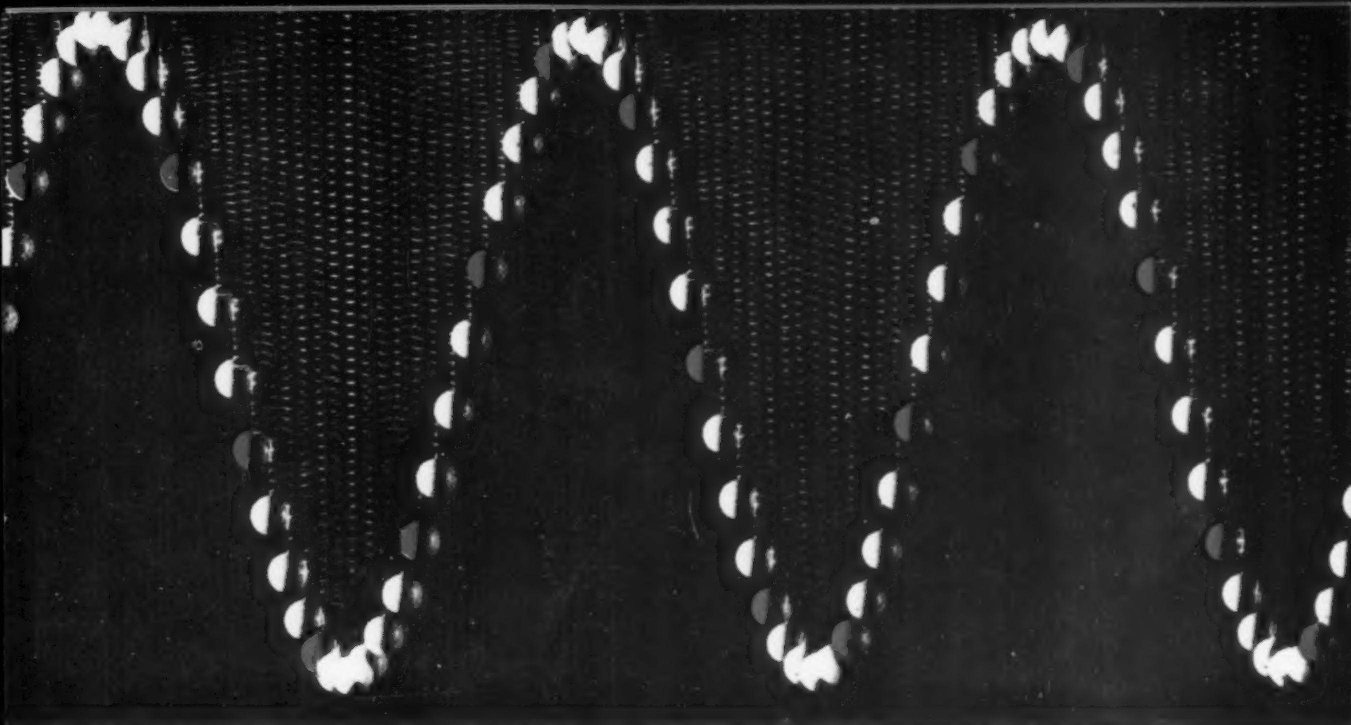


ratios of the mass of ions to single electrons, and an interferometer that uses high frequency sound waves in place of the more usual light waves.

The rotating cylinder built by Rogers Ritter of the University of Virginia was designed to be so nearly frictionless that, theoretically, once started spinning it wouldn't stop for 100 billion years. Measurements made on the actual behavior of the cylinder will serve as tests for such diverse questions as "Does the local force of gravity vary with time?" (It might.) or "Is new matter being constantly created in the Universe?" (One theory says yes.)

The cryogenic device built by Robert Van Dyck, Jr., of the University of Washington, was designed to measure, with a significant improvement in accuracy, mass ratios that could affect the accepted values for a whole series of natural constants such as the Avogadro number, the proton gyromagnetic ratio, the Faraday constant, and the magnetic moment of the proton.

Similarly, the ultrasonic interferometer being built by William Sauder of the Virginia Military Institute merges traditional methods for measuring the speed of sound in a gas with the design advantages of the venerable Michelson interferometer into an imaginative device that is expected to provide data in a year or so to help refine the value of the gas constant in classical physics.

Such projects are usually neither very large nor very prominent. A basic goal of the Precision Measurement Grants Program is to encourage researchers in academic institutions to pursue new measurement ideas—ideas for which it might otherwise be difficult to find funds, as a sort of investment in innovative research.

One of the early administrators of the Precision Measurement Grants Program, Richard Deslattes, recalls, "The feeling was that the area of precision measurement and the study of fundamental constants was a particular responsibility of the Bureau. This work is usually not very well supported in the universities. The proposal was that with a fairly small grants program we could, to a limited extent, fill in this gap in academic research. One could not start research on what we could give, but if the project was already in progress, the little bit extra could provide for a measurement or refinement that otherwise might not be done."

"The whole point," agrees Barry Taylor, the physicist who has administered the program for the last 6 years, "is that when research money is scarce, as it has been for the last decade, it's tough for a young researcher to get funding, especially in this area. Precision measurement and fundamental constant work tends to fall through the cracks at funding agencies such as NSF (the National Science Foundation, the country's largest dispenser of research grants). Here we saw a chance to get some useful research done in an area of particular interest to us and at the same time help along the experimental work of young people who

have demonstrated a high level of competence."

The amount of money, Deslattes notes, is not large by the standards of modern physics research. The initial grant for the past several years has amounted to $25,000 a year, renewable at the discretion of NBS for up to 2 more years. Next year the amount will go up to $30,000—not enough to build an experiment from the ground up, but enough to modify an existing project to satisfy some goals of the grants program.

What sort of research does the money buy? The current grants described here are more or less typical of the program.

Gravitational Waves

Oelfke's project bears directly on attempts at several laboratories to detect the still-hypothetical "gravitational waves" by which, according to current physics theory, the force of gravity is propagated in much the same way that electromagnetic force is propagated by electromagnetic waves. Because of the very weak and subtle effects involved, Oelfke's work takes him literally to the limits of measurement science.

Several experiments have been launched to measure, or at least detect, waves of gravity from astronomical sources such as supernovae, which are presumed to be fairly strong. One of the favorite methods uses a so-called "resonant-bar antenna," consisting of a massive (up to 10 tons) bar of metal or crystal, which would move ever so slightly in response to passing gravitational waves. Aluminum has been used, as well as sapphire and silicon. The trick comes in detecting the wave-caused movement, which, even from a source like a supernova, would be very small. Estimates are on the order of 10^{-19} cm.

To even notice the movement caused by a passing gravitational wave—which, in theory, causes a sort of twisting of the geometry of space in different dimensions—all other sources of vibration must be eliminated. The bar is carefully isolated from outside influences and, in more recent experiments, cooled to within a degree or so of absolute zero to slow the internal vibrations of the antenna's molecules. At this point the mechanical energy in the bar is so low that physicists talk of it in terms of "phonons," tiny quantums of mechanical energy analogous to the photon, the smallest possible quantum unit of radiant energy. Such an "antenna" may have only a thousand or so phonons of energy, according to Oelfke, mostly in the form of a very slight vibration at the principal resonant frequency of the bar, the pitch at which it naturally rings like a bell. In theory, a passing gravitational wave, twisting the space of the bar, may add a few extra phonons of energy to the bar at its resonant frequency, and these phonons might be detected.

The problem is, detected *how*? These are not what one calls gross effects. The typical wave effect expected from the collapse or explosion of a star would move the bar a fraction of the diameter of an atomic nucleus. One of the original suggestions was to put motion-sensing transducers on the bar, but the action of the transducers themselves creates disturbances in the bar, losing the gravitational waves in the "noise."

This is not because of carelessness. Experimenters are trying to detect effects so minute that they take place in the realm of quantum mechanics—the theory that governs the behavior of things at the smallest levels of existence—and the researchers' backs are against a particularly unyielding wall known as the Heisenberg uncertainty principle.

The uncertainty principle sets an absolute upper limit on the accuracy of quantum mechanical measurements: the uncertainty in the values of any two quantum mechanical variables that share a mathematical relationship, such as position and momentum, can never fall below a certain value for any given pair of measurements. The reason, according to theory, is that the very act of measurement affects the thing you are measuring in some unpredictable way. This unpredictable effect—sometimes called a "back reaction"—rules out most of the measurements of the gravitational wave antenna that could detect any change in its motion due to the wave.

Other things can be measured, though, and this is where Oelfke's work comes in. As is typical of the program, the research for which Oelfke received a Precision Measurement Grant is only a small project when compared to gravitational wave experiments (and, for that matter, only a part of Oelfke's own work). However, if successful, it will be an important addition to the art of quantum measurements. Oelfke proposes an experiment that may beat the system.

His is one of the first attempts to make practical use of the comparatively new theory of "quantum nondemolition measurement." First proposed as recently as 1974, QND measurements are based on the idea that, although the uncertainty principle can never be violated, it *can* be avoided. If you do not ask the experiment for too much information, you won't be limited by the uncertainty principle.

This is interesting, so let's digress. Think of the antenna as a pendulum, swinging back and forth at its basic frequency. You wish to know if an outside force affects the pendulum. The obvious thing to do is to observe the pendulum path, how high it goes, or even its phase (that is, at what time it is swinging up, at what time it is swinging down, and so forth), and look for an unexpected change. The problem is that every time you look at the pendulum, its motion changes randomly. *You* are an outside force.

This analogy breaks down fairly quickly because the pendulum obeys the laws of classical physics, whereas the quantum mechanical system of interest to gravitational wave researchers is somewhat different—and less definite. But pretending that they are similar, one thing you can know quite precisely about the pendulum is its period of oscillation, the time it takes to swing back and forth once.

Armed with this, you can take an instantaneous look, like a flash photo, of the pendulum and not its position. This kicks the pendulum off on some random swing about which you know nothing, but exactly one period later, it will return to the same place, and another flash photo at that time should find the pendulum in the same position.

If it's *not* in the same position, something has happened in the meantime. Another outside force has kicked the pendulum and set it off on a different swing. This, of course, is what you are looking for.

That, greatly simplified, is the basis of Oelfke's experiment. He refers to it as stroboscopic measurement. "It's like strobing a fly wheel to tune an engine; the light hits the same point every time when the frequencies are matched. In principle, one point can be measured exactly, and if another force acts on the system, that point will shift. Where the analogy breaks down is that you can't predict the motion of the flywheel in between points. It could get bigger or smaller or go through any change you can think of," he explains. "You can't apply this to any old physical measurement and cheat the uncertainty principle, but it can be done in this case. We're throwing away as much information from the antenna as we can and still save enough to measure a force acting on it. We really don't care what the antenna does as a classical oscillator, only about the nature of outside forces acting on it. What the theory actually says is that we are very seriously limiting the back reaction by narrowing the information we take from the system."

Dr. William Oelfke of the University of Central Florida is shown with part of the mechanical harmonic oscillator he developed for use in gravitational wave experiments. The oscillator, which operates at temperatures of about 3 kelvins, is in use on the gravitational wave antenna project at Louisiana State University.

In addition, says Oelfke, the measurement can't really be "stroboscopic" in an actual experiment for a number of reasons. For one thing, an absolutely instantaneous measurement is impossible. The "flash photo" takes some finite amount of time. Instead, the measurements are made "synchronously,"a concept that does not translate well from the mathematics. It means, vaguely, that the measurement process is continuous, but the measurement system is synchronized to the movement of the oscillator. ("You sit on the flywheel and spin with it.")

The actual device used by Oelfke is a fairly complicated accelerometer consisting of a supercooled niobium diaphragm that divides a small container into two equal cavities that resonate at radio frequencies. The "synchronous" effect is achieved with an amplitude-modulated radio-frequency oscillator that drives the resonant cavities at a frequency near the resonant frequency of the harmonic oscillator that serves as a gravitational wave antenna. Minute changes in the position of the diaphragm produce corresponding changes in the resonant frequency of the cavities that can be detected electronically. The design, according to Oelfke, is based on theories worked out by a

number of people, including Carlton Caves and Kip Thorne of the California Institute of Technology, and Vladimir Braginsky of Moscow University.

Oelfke is now working in cooperation with a gravitational wave experiment conducted by William Hamilton at Louisiana State University. Part of the work done under the Precision Measurement Grant will include modifying the accelerometer to work at even lower temperatures (which reduces interference) and testing the system.

Is it all worth it? Writes Oelfke, "This . . . improvement in sensitivity may well make the difference between 'seeing' Virgo Cluster stellar collapse events and not seeing them at all."

"Trapped" Atoms

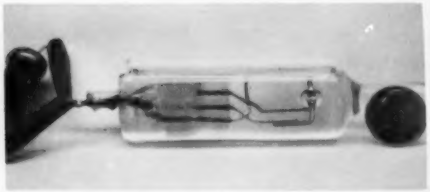
Wing's project is perhaps less impenetrable than Oelfke's, but it is no less elegant. He is constructing a device to trap neutral atoms.

"Trapping" particles the size of atoms or small molecules is not unknown. Ions—particles carrying an electric charge—can be captured in one of several types of traps that use electromagnetic fields, rather than solid containers, to hold the ions. Such traps are used in particularly delicate experiments in spectroscopy, photodissociation, and similar fields where the experimenter wants to hold the particle within the experimental apparatus for a reasonable length of time, free from disturbing conditions. (A "reasonable" length of time needn't be very long—several millionths of a second, for instance—or it could be several hours.) To date, however, only ions could be contained in such traps, because the basic principle depends on the charge of the particle. The trap works because the ion is repelled (or attracted) by electromagnetic fields.

Wing believes that, under certain conditions, electrically neutral atoms (or molecules) could be confined in similar traps. His idea is based on the so-called "Stark effect," a shift in the energy levels of an atom caused by the presence of an electric field. Although atoms in their lowest energy state (or ground state) have negative Stark energies and thus will drift *toward* an electrode, says Wing, if some atoms are excited to properly chosen higher energy states, they will have positive Stark energies and drift *away* from electrodes in a static electric field. Thus, according to Wing, it should be possible to create a simple static electric field with a geometry similar to that used in ion traps that can hold excited neutral atoms.

Of course, the path between idea and functioning system is more complex than this implies. There are a number of questions yet to be answered. The concept won't work for just any atom or molecule. Which ones are suitable and why? What is the best design for the trap? Once excited, how can you keep the particle excited for the time required by some experiments? Would laser radiation do it? How?

Pending answers to these and other questions, Wing's idea will provide a new tool for such things as high-resolution spectroscopy and may lead to new ways of testing the fundamental postulates of the present theory of atomic structure, which is known as quantum electrodynamics.



This demonstration "mock-up" imitates the principles of Wing's electrostatic trap for neutral particles by trapping small, uncharged air bubbles in high-voltage oil. The "trap," located in the right-hand side of the device, consists of two stainless steel screw heads for electrodes and a stainless steel washer for a ring electrode. When a 5 kilovolt potential difference is between the screw heads and the washers, small bubbles that simulate Rydberg atoms with positive Stark energies are drawn in towards the center of the hole in the washer.

Dr. William Wing, University of Arizona.

"Reservoirs of Talent"

Although precision measurement research is usually the oft-neglected stepchild of physics, as NBS's Taylor generally points out in aggrieved tones, the 10-year-old Precision Measurement Grants program is attracting favorable attention. The Bureau, according to Taylor, is now discussing with the prestigious National Science Foundation a possible arrangement to expand the grants program, perhaps to twice its current size.

Taylor himself has no doubts about the value of the program. "It enables us to both nurture and tap the large reservoir of talent that exists in our universities in the precision measurement field," he says. "We support people, we encourage them, and we get them to do work that is very useful to us and to the science." □

ON LINE WITH INDUSTRY

NEW PARAMETER PROPOSED FOR FRACTURE TOUGHNESS

by Collier Smith

Fracture toughness tests are routinely performed on small samples of metals and their alloys, but problems sometimes arise in extrapolating results to predict the behavior of actual structures. Research at the Fracture and Deformation Division of NBS is pointing toward a new solution to these problems.

Fracture mechanics, the study and analysis of how cracks develop and grow in structural materials, is fairly new as a quantitative science, although the problem has been with us since the first stones were piled one on another until one cracked and gave way. As a distinct discipline, it dates back approximately to the 1920's, when the analysis of the behavior of cracks began. It was not until the 1950's, however, that the analyses were of practical use when applied to metals.

Three "micromechanisms" of fracture have been identified in metals: microvoid coalescence (MVC), cleavage fracture, and intergranular fracture. MVC occurs when tiny voids—especially around particles of impurities in the material—grow under stress, link together, and finally cause the material to break. Cleavage fracture means breaking along the crystallographic planes of the grains that constitute most metals. Intergranular fracture involves the separation of neighboring grains along the boundary between them. Which of these micromechanisms is involved in a given fracture depends on the type of material and how it is loaded. Micromechanism analysis gives us an idea of how a given crack causes failure in a structural member, but doesn't tell us what we really want to know: how strong is a certain structural member?

This question usually must be answered by a testing program. Samples of the proposed material are notched and precracked by fatigue cycling and then pulled apart or bent until the crack grows. Measurements of the force and the amount of displacement ("stretch") are combined with data on the dimensions of the sample to give a measure of fracture toughness. Common parameters yielded by these procedures are K_{Ic}, the J-integral, and crack tip opening displacement, C(T)OD, values. Basically, they indicate the amount of energy needed to cause fracture.

A problem arises when test results are scaled up to working size. Tests cannot always be made on full-sized specimens because of a lack of hydraulic testing machines of sufficient size, or simply because of the cost of the samples. However, large pieces often behave differently from small ones, particularly in the presence of a crack. Structural materials with cracks are not as fracture-resistant (strong) as their size would indicate they should be because of the strain concentration near the crack tip. The scaling problem is particularly difficult for the elastic-plastic case, i.e., intermediate between brittle (glass-like) and ductile (fully plastic) fracture. Most fractures in steel structures such as bridges and pipelines tend to occur in a ductile-to-brittle transition temperature region. A means of removing the size dependence is needed so that results from small samples can be applied to large structural members.

Research in this field has been of great interest to designers, builders, and users of metal structures, and many related industries have cooperated by providing financial support through The Welding Institute at Cambridge, England. Michael Dawes of The Welding Institute has served as a consultant under contract to NBS at its Boulder Laboratories, directing work in the Fracture and Deformation Division on a method to provide the needed geometry and size independence. Dawes proposes a new parameter, which he designates as "M," to be used with the present J-integral and C(T)OD data in fracture mechanics. "M" is a factor that takes cognizance of the size and geometry of the structural member, its material properties, and even the form of loading (e.g., tension or bending), and provides a more universal parameter to help predict fracture toughness in full-sized structural members.

Each material and micromechanism has a critical value of "M," which is calculated from the equation $M_c = (K_{Ic}^2/E) \times$ (scaling factor). K_{Ic} is a measure of the linear elastic limit of fracture toughness, E is the elastic modulus, and the scaling factor is a function of the size of the cracked body, loading conditions, and material properties. Thus, "M" relates the analysis to the linear elastic region where geometry effects are minimal. The scaling factors must be determined experimentally for various materials and temperatures before "M" can be applied across the board to test results, but it appears to offer a significant improvement in cost and accuracy over present methods. The NBS Fracture and Deformation Division, among others, is developing analytical methods to calculate the scaling factors.

Dawes, on sabbatical leave from his position as head of the Brittle Fracture Laboratory at The Welding Institute, said he relished the 6 months spent at NBS while he formulated his concept of the fracture toughness parameter.

"After a number of years in fracture research, I had a lot of unconnected ideas floating around in my head on fracture at the atomic, microscopic, and macroscopic levels. Here, away from the daily administrative details that I face in England, I was able to synthesize the concepts into what turned out to be a relatively simple factor. Of course, determining critical values of 'M' won't be trivial, but it should be a straightforward procedure."

Dawes has returned to England but will revisit NBS soon to complete the final aspects of his work here in the areas of elastic-plastic fracture and fracture toughness test methods.

Smith is a writer and information specialist in the Boulder Program Information Office.

STUDY EVALUATES SOLAR COLLECTOR COVER PLATES

Heat and sunlight caused permanent deterioration in most of the plastic cover plates of flat plate solar collectors in a recent study at the National Bureau of Standards' Center for Building Technology. Materials evaluated were typical of cover plates for flat plate solar collectors at the time the study was initiated.

Conducted for the Department of Energy, the 4-year project was aimed primarily at collecting laboratory data for the development of standards for solar cover plate materials. "The literature contains little data on what happens to these materials when they're exposed to conditions experienced in solar collectors," says project leader Elizabeth J. Clark. Ten materials, including glass, plastic sheet, and plastic film, were evaluated to assess their durability after exposure to heat aging, natural weathering, and accelerated weathering.

Transmittance of solar energy was the major variable under investigation. Results indicated that transmittance losses through the cover plates are caused by several weathering factors—solar radiation, moisture, and air pollutants.

A related finding confirmed that dirt and dust retention are a major cause of solar energy transmittance losses in cover plates. According to researchers, dirty plates could block the transmittance of as much as 5 percent of available solar energy. Tests on 10 different cover plate materials showed that transmittance losses due to dirt and dust often equaled or exceeded losses due to natural weathering. However, natural weathering caused permanent transmittance losses, but dirt was removable.

Besides solar energy transmittance, the researchers measured linear dimensional stability and warpage and determined how these material properties were affected by heat and solar radiation—two major environmental degradation factors for solar collectors.

According to Clark, the test procedures used by the researchers to simulate those degradation factors proved effective in identifying materials that will develop problems in outdoor weathering. To simulate aging, two laboratory tests were used: heat aging in an oven and exposure to artificial solar radiation. Natural weathering was tested by actual outdoor exposure of material samples on "minicollectors." Materials were mounted outdoors on small boxes simulating collectors and evaluated at the temperatures they would normally reach on larger collectors in actual use.

The combination of simulated and natural weathering allowed the NBS researchers to compare the exposures and to assess the simulated weathering. Artificial weathering with a xenon arc light, Clark notes, is also helpful in distinguishing materials sensitive to solar radiation.

Test results from the NBS Gaithersburg, Maryland, laboratories and from sites in Arizona and Florida also revealed that the rate at which optical, mechanical, and physical properties of the cover plate materials deteriorate may be related to solar radiation dosage.

A 157-page report, *Solar Energy Systems: Standards for Cover Plates for Flat Plate Solar Collectors* (TN1132), describes the project's research methods and results, as well as further research needs. Included in the report are two draft standards previously submitted to the American Society for Testing and Materials (ASTM) for consideration as consensus standards. One of these is a standard for evaluation of cover materials for flat plate solar collectors; the other is a standard practice for exposure of cover materials to natural weathering under conditions simulating the stagnation mode. These draft standards have formed the basis for two recently approved ASTM standards.

The report may be ordered by Stock No. 003-003-02277-2 for $5.50 (prepaid) from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. *E. R.*

Minicollectors featuring different cover plate materials are placed on a rack and exposed to solar radiation and natural weathering in Gaithersburg, Md.

IMPROVED MODELING OF CEMENT AND CONCRETE

Researchers at the NBS Center for Building Technology have begun a multi-year program to develop a better knowledge of cement hydration, an effort that should lead to improved understanding of the basic reactions in the manufacture and use of cement and concrete. It is intended that the results of this research, which will be expressed in the form of mathematical models, will provide a basis for better predictions of how cement and concrete will perform in actual use.

James R. Clifton, Structures and Materials Division, B348 Building Research Building, 301/921-2630, and James Pommersheim, Bucknell University.

Concrete is the most widely used man-made building material in the United States—about 675 million metric tons are used annually. Despite the heavy investment of materials and energy in cement manufacture and use, the selection of materials for use in concrete is still largely empirical, and the factors controlling the performance and durability of concrete are not adequately understood. The work at NBS should ultimately affect predictions of service life of concrete and should aid energy and material conservation in the cement and concrete industries.

Because tricalcium silicate is the major constituent of portland cement and, along with dicalcium silicate, is principally responsible for the development of strength in the concrete, its hydration is the initial focus of the research. A description of a possible mathematical model for the hydration of tricalcium silicate has recently been published by Clifton and Pommersheim*.

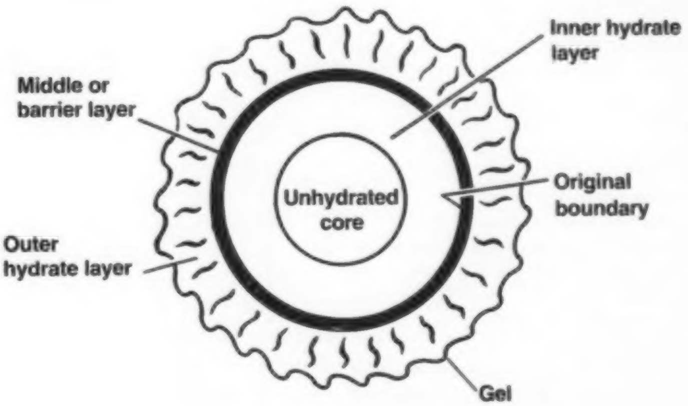
The model is based on widely accepted conceptual models of the hydration process and consists of three separate rate-controlling stages corresponding to the phenomenological stages of the conceptual model. While each hydration stage involves different controlling phenomena, chemical reactions and diffusion processes occur in all stages.

The figure is a schematic presentation of a single hydrating grain of cement. Inner and outer hydrate layers are shown as well as a middle product layer. The hydrate layers consist of two different gels in varying amounts but in constant proportion to each other.

When physically realistic values were used for the parameters, the model was found to give a reasonable fit with the limited amount of published data. If the particle size of tricalcium silicate, the water-to-tricalcium silicate ratio, and the hydration temperature are known, the following variables can be obtained as functions of time: degree of hydration and hydration rate; amount of calcium hydroxide and gel formed; intergranular porosity; amount of free and combined water; and the rate-controlling process.

This mathematical model is the first phase in applications of models to the hydration of calcium silicates and other simple cement systems. Submodels are in process of development to predict rate of heat release as a function of hydration time and to determine the effects of particle size distribution and temperature on hydration rates.

Over the course of the research program, which is led by Geoffrey Frohnsdorff, NBS will test mathematical models experimentally and revise them as necessary, especially when mixtures of cement compounds and portland cements are studied. Because of the growing interest in mathematical modeling of reactions of cements, the Bureau is cooperating in the organization of a committee on mathematical modeling of cement hydration in RILEM, the International Union of Materials and Structures Research and Testing Laboratories.



Schematic representation of a hydrating tricalcium silicate grain.

Pommersheim, J. M., and Clifton, J. R., "Cement and Concrete Research," Vol. 9, pp. 765-770, Pergamon Press, Ltd., Printed in United States, 1979.

FIRE DEVELOPMENT IN BASEMENT ROOMS

The fire performance of construction materials and assemblies is conventionally determined by subjecting the building components and structural elements to a standardized exposure in a laboratory fire endurance test. Due to extensive research on compartment fires and increased information available on fire behavior, some doubts have been raised about the validity of the test environments relative to actual fires.

Jin Bao Fang and J. Newton Breese, Fire Performance Evaluation Division, A345 Polymers Building, 301/921-3744.

The ASTM Standard E119 time-temperature curve has been used widely in the United States for over 60 years. The curve was developed in 1917 based on experience derived from all the known temperatures measured or inferred from building fires and from fire tests made at various institutions such as the New York Building Code Authority and Columbia University. No major change has been made in the curve since then. The design of residential buildings has changed considerably in the past 6 decades, with the use of lightweight construction instead of heavy masonry and large windows rather than small ones. Also, many new products, including synthetic fabrics, finishes, laminates, and composites, have been introduced as the primary components of furnishings and lining materials in residential rooms. These materials tend to burn more rapidly and may lose their integrity earlier and at lower temperatures than woodbase materials. The real temperature development can be expected to be quite different from the temperature history described by the 1917 standard curve.

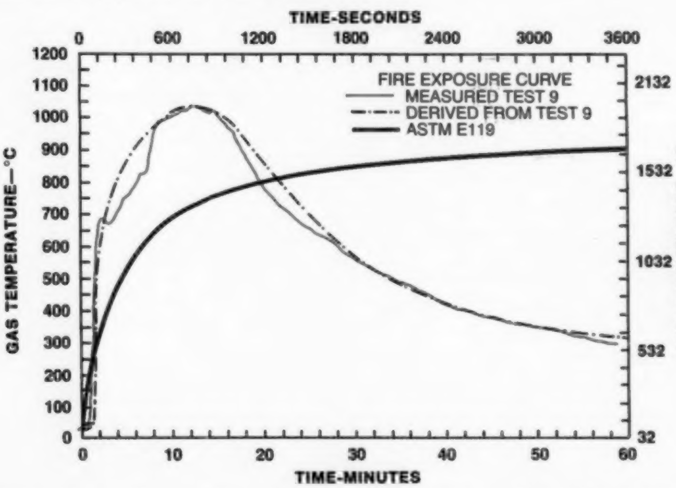
To establish the fire resistance required for a structure or a partition to withstand the action of a fully developed fire without losing its structural integrity, insulating function, or load carrying capacity, it is necessary to estimate the severity and duration of the expected fire.

The overall objectives of the fire endurance study at NBS are to develop a meaningful test procedure for more realistic evaluation of the fire resistance of floor/ceiling assemblies in residential occupancies and to suggest improved performance criteria for the fire-safe use of load-bearing structural components. The first phase of this research was specifically aimed at characterizing the behavior of fires originating in typically furnished basement recreation rooms. The technical data gathered was used to develop a mathematical model of fire growth and a rational set of fire exposure conditions applicable to the fire resistance testing of residential floor constructions.

We conducted a series of 16 full-scale room burnout tests over a range of typical fire load densities, room sizes, ventilation conditions, and interior finish materials. The data include a description of the fire growth process in the fire room; the time to room flashover; the time when flames emerged from the doorway; the time histories of the upper gas temperature; the rate of heat release within the room; the developed static pressure and heat flux levels at selected locations; and the fire-induced air flow at the door opening.

Based on the experimental results of the tests, we have reached the following conclusions:

- The rate of development and the intensity of real fires involving the burning of typical furniture and interior linings in a room during the first 20 minutes may be significantly greater than those defined by the ASTM E119 standard time-temperature curve. A more realistic time-temperature curve for residential occupancies is presented in the figure.
- Room flashover did not occur for a closed room of the size tested, even with normal forced air ventilation. However, for fires involving a single open doorway the rate of heat release within the room increased with addition of a forced air supply.
- While the intensity of the fire within the room was controlled by the available air supply, the rate of burning outside the room was markedly increased due to the additional fuel produced by combustible materials on the wall and ceiling. This could be a major factor causing fire to spread beyond the room of origin.
- The effect of the room size on the fire intensity was small, although the duration of the fire increased with an increase in room dimensions for the same movable fire load density.



Comparison of fire exposure curve derived from room fire test 9 and ASTME E119 standard curve.

GENERATION AND MEASUREMENT OF DC ELECTRIC FIELDS WITH SPACE CHARGE

Characterization of the electrical environment in the vicinity of high voltage dc transmission lines requires measurement of a number of electrical parameters associated with the lines. These parameters include the electric field strength with significant space charge contributions. Researchers at NBS have developed a parallel-plate apparatus for generation of known dc electric fields with controllable amounts of space charge. It has been used to examine two types of field probes currently used for transmission line electric field measurements.

Martin Misakian, NBS Electrosystems Division, A347 Metrology Building, 301/921-3121.

With the gradual growth of dc transmission of electrical energy has also come an interest for a full characterization of the electrical environment in the vicinity of high voltage dc (HVDC) transmission lines. Because some corona is usually associated with normal operation of HVDC lines, this environment is complicated by the presence of space charge. At the present time, probes used for the measurement of HVDC transmission line electric fields at ground level are calibrated with space-charge-free fields produced between parallel plates.

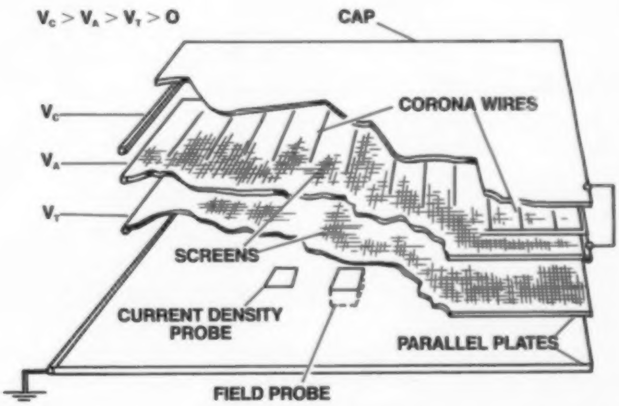
The Electrosystems Division has now developed a parallel-plate apparatus for generating known dc electric fields with space charge. Experimental uncertainties have been determined and are used to estimate the possible error in calculated values of electric field strength. Electric fields known to an estimated accuracy of ± 2 percent can be obtained with the apparatus.

The apparatus has already been used to evaluate the performance of two types of field probes currently employed to measure electric field strength near dc power transmission lines. Use of the probes to determine the space charge mobility provides information on the performance of the instrumentation as well as on the operation of the apparatus. The data indicate that a field mill (so-called because of a fan-like rotating blade component similar to a chopper) with phase sensitive signal detection functions well in the presence of high current densities, but, under the same conditions, the more widely used field probes with a vibrating-plate design give erroneous results.

With a valid *in situ* determination of mobility, known fields of arbitrary strength and controllable amounts of space charge can be produced. The data show that, for a given field strength, the performance of the vibrating-plate probes improves as the current density is reduced. Only cases where the space charge contribution to the total field strength is significant have been considered. Future dc transmission systems, as well as biological exposure facilities presently under construction, will produce current densities that are comparable to the values used in the NBS studies.

Measurements of dc fields containing space charge will become increasingly important if more dc lines become the choice for future transmission systems. The Department of Energy has established a program to assess the benefits and potential hazards associated with increased dc transmission of electrical energy; the dc-field apparatus is part of a project at NBS to provide measurement support for this program. (The Center for Electronics and Electrical Engineering's Electrosystems Division had already completed the development of calibration techniques for instruments used to measure the electric field from ac power lines, presently the most common type of line used in the United States.)

A description of the apparatus and the results of field meter evaluations are given in NBSIR 80-2177, "Generation and Measurement of DC Electric Fields with Space Charge."



Cross-section of apparatus. The configuration shown is appropriate for generating an electric field $\bar{E}$ with positive space charge and current density J.

CONFERENCES

For general information on NBS conferences, contact JoAnn Lorden, NBS Public Information Division Washington, DC 20234, 301/921-2721.

IEEE SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Some 500 attendees are expected at the Institute of Electrical and Electronics Engineers' 1981 International Symposium on Electromagnetic Compatibility to be held August 18-20 at the University of Colorado in Boulder, Colorado.

Problems of electromagnetic compatibility and electromagnetic interference are growing almost daily as new electronic products and systems come into use. Designers and engineers will find the EMC Symposium extremely helpful in providing information on how to measure and ameliorate problems of unwanted electromagnetic radiation.

The symposium will feature workshops on FCC measurements and electromagnetic properties of composites. There will be special sessions on electromagnetic compatibility design in microelectronics, electromagnetic environments, and lightning. Regular sessions will cover a wide variety of topics including communications, static discharge, spectrum management, transmission lines, and standards and regulations.

Copies of the preliminary program and registration information can be obtained by writing to: Charlotte Tyson, Registrar for EMC'81 IBM, 59Z/025-1, P.O. Box 1900, Boulder, CO 80302 or call 303/447-5072. Harold E. (Bud) Taggart of the National Bureau of Standard's Boulder Laboratories chairs the Symposium Steering Committee.

CONFERENCE CALENDAR

June 1-3
6TH INTERNATIONAL SYMPOSIUM ON IMAGING AND ULTRASONIC TISSUE CHARACTERISTICS, NBS, Gaithersburg, MD; sponsored by NBS, NIH, IEEE, and AIUM; contact: Melvin Linzer, A366 Materials Building, 301/921-2611.

June 3-5
ASTM G-2 SYMPOSIUM ON FRETTING WEAR, NBS, Gaithersburg, MD; sponsored by NBS and ASTM; contact: Arthur W. Ruff, B114 Materials Building, 301/921-2966.

June 8-12
SECOND INTERNATIONAL CONFERENCE ON PRECISION MEASUREMENTS AND FUNDAMENTAL CONSTANTS, NBS, Gaithersburg, MD; sponsored by NBS, IUPAP, and AMCO; contact: Barry N. Taylor, B258 Metrology Building, 301/921-2701.

June 15-19
INTERNATIONAL JOINT CONFERENCE ON THERMOPHYSICAL PROPERTIES, NBS, Gaithersburg, MD; sponsored by NBS, ASME, and Purdue University; contact: Ared Cezairliyan, Room 124 Hazards Building, 301/921-3687.

June 18
20TH ANNUAL ACM SYMPOSIUM, University of Maryland, College Park, MD; sponsored by NBS and ACM; contact: Wilma Osborne, A265 Technology Building, 301/921-3485.

August 10-14
CRYOGENICS ENGINEERING CONFERENCE (CEC) AND THE INTERNATIONAL CRYOGENIC MATERIALS CONFERENCE (ICMC), San Diego, CA; sponsored by NBS and Cryogenic Engineering Conference; contact: Dee Belsher, Program Information Office, Room 4001-Building 1, Boulder, CO 80303, 303/497-3981.

September 14-16
SECOND INTERNATIONAL CONFERENCE ON THE DURABILITY OF BUILDING MATERIALS AND COMPONENTS, NBS, Gaithersburg, MD; sponsored by NBS, ASTM, NRC of Canada, International Council for Building Research Studies and Documentation, International Union of Testing and Research Laboratories for Materials and Structures; contact: Geoffrey Frohnsdorff, B348 Technology Building, 301/921-3485.

October 7-9
36TH CALORIMETRY CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS and University of Colorado; contact: Robert Goldberg, A303 Physics Building, 301/921-2752.

October 13-15
6TH ANNUAL CONFERENCE ON MATERIALS FOR COAL CONVERSION AND UTILIZATION, NBS, Gaithersburg, MD; sponsored by NBS, DOE, EPRI, and GRI; contact: Samuel Schneider, B308 Materials Building, 301/921-2894.

***November 23-24**
DEFORMATION, FRACTURE, WEAR, AND NONDESTRUCTIVE EVALUATION OF MATERIALS: PHYSICS AND PRACTICE, New Orleans, LA, sponsored by NBS and APS, contact: Robb Thomson, A113 Materials Building, 301/921-2103.

***December 8**
COMPUTER NETWORKING SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS and IEEE; contact: Robert Toense, B226 Technology Building, 301/921-3516.

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***January 19-21**
SYMPOSIUM ON SILICON PROCESSING, San Jose, CA; sponsored by NBS and ASTM; contact: Elaine Cohen, A308 Technology Building, 301/921-3786.

***March 15-17**
HUMAN FACTORS IN COMPUTER SYSTEMS, NBS, Gaithersburg, MD; sponsored by NBS and ACM; contact: Seymour Jeffery, A247 Technology Building, 301/921-3531.

**New Listings*

PUBLICATIONS

A FORTRAN PROGRAM FOR CALCULATING

*Larrabee, R. D., Thurber, W. R., and Bullis, W. M., A FORTRAN Program for Calculating the Electrical Parameters of Extrinsic Silicon, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-63, 54 pages (Oct. 1980) Stock No. 003-003-02260-8, $3.75 prepaid.**

This publication of the National Bureau of Standards Semiconductor Technology Program presents a complete FORTRAN program for calculating several important electrical properties of silicon based on the impurities present in the silicon and the temperature of interest.

Because trace impurities may act as both electron donors and acceptors in silicon, they can have a profound effect on the electrical characteristics of the semiconductor. This program takes as inputs the density, activation energy, and degeneracy of all active donors and acceptors in the system of interest, calculates the Fermi level by solving the detailed charge balance equation, and then uses the position of the Fermi level to calculate several often-used electrical parameters that depend on carrier density or scattering, such as resistivity, carrier mobility, and the Hall coefficient.

Results obtained from this program have been useful in interpreting Hall effect data, determining the degree of ionization of the separate dopant states as a function of temperature, predicting the behavior of specimens when the dopant picture is intentionally (or conceptually) changed, and understanding the variations in the relative roles of the different scattering mechanisms on carrier mobility as the temperature is changed.

** Publications cited here may be purchased at the listed price from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (foreign: add 25 percent). Microfiche copies are available from the National Technical Information Service, Springfield, VA 22161. For complete periodic listings of all scientific papers and articles produced by NBS staff, write: Editor, Publications Newsletter, Administration Building, National Bureau of Standards, Washington, DC 20234.*

NDE METHODS TO MEASURE MOISTURE IN BUILT-UP ROOFING SYSTEMS

Knab, L. I., and Mathey, R. G., NBS and Jenkins, D. R., University of Central Fla., Orlando, FL, Laboratory Evaluation of Nondestructive Methods to Detect Moisture in Built-Up Roofing, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 131, 173 pages (Jan. 1981) Stock No. 003-003-02281-1, $5.50 prepaid.

Moisture in insulated built-up roofing systems causes many premature roof failures and unwanted energy losses. NBS researchers have investigated a promising approach for improving the reliability of roof inspection and maintenance through the use of nondestructive evaluation (NDE) methods that can detect moisture in the interior of roofing systems.

Electrical capacitance, nuclear backscatter, and infrared thermography are the most common commercially available NDE methods used to detect moisture. Since considerable uncertainty has existed in the use of these methods, a comprehensive NBS laboratory study of them was carried out to determine their accuracy and reliability and to establish their moisture detection capabilities.

This laboratory study investigated the reliability and accuracy of these three types of NDE methods to quantitatively determine the moisture content of the insulation in built-up roofing specimens. Thirty-six roofing specimens, which consisted of five types of rigid-board roof insulations with attached bituminous built-up membranes, were tested over both concrete and steel decks. A wide range of moisture content was induced into the specimens by maintaining a constant water vapor pressure difference across them.

Two performance characteristics of the NDE methods were evaluated: the minimum moisture content that a method could detect; and the relationship between NDE response and moisture content beyond the minimum detectable moisture content. The two performance characteristics were assessed through normalization parameters defined in terms of the NDE response and its scatter about a fitted curve. There were differences in the performance characteristics, the magnitude of which depended on the NDE method, the specimen composition, and the deck type used.

NBS Building Science Series Report No. 131 presents the full details and conclusions of the analyses of the two performance characteristics and results of the studies.

Further information may be obtained from L. I. Knab, B348 Building Research Building, National Bureau of Standards, Washington, DC 20234.

FEDERAL METROLOGY AND CALIBRATION CAPABILITIES CATALOG

Leedy, K. O., Calatog of Federal Metrology and Calibration Capabilities, Nat. Bur. Stand. (U.S.), Spec. Publ. 546, 1980 Edition, 69 pages (Sept. 1980) Stock No. 003-003-02251-9, $4 prepaid.

The National Bureau of Standards has published a 1980 edition of its *Catalog of Federal Metrology and Calibration Capabilities*. Compiled under the NBS Precision Measuring and Test Equipment (PMTE) Program, the new volume updates the listings of the 1979 edition.

The catalog includes a list of Federal laboratories doing metrology and calibration work, the particular capabilities of each laboratory, its address and phone number, and the name of a person at each laboratory to call for further information. Listings are by laboratory, by type of service, and by geographical location.

The Precision Measuring and Test Equipment Program at NBS was started to encourage cooperation among Federal calibration and metrology laboratories and to improve the accuracy and efficiency of these facilities.

COMPUTER MODEL DOCUMENTATION GUIDE

Federal Computer Performance Evaluation and Simulation Center, Computer Science and Technology: Computer Model Documentation Guide, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-73, 56 pages (Jan. 1981) Stock No. 003-003-02282-9, $3.75 prepaid.

Documentation for computer models is an essential element in management decision-making, model conversion, and model transfer. Now the National Bureau of Standards has provided a *Computer Model Documentation Guide* (SP 500-73) that will assist managers, users, analysts, and programmers in the documentation process. The publication includes separate guidelines for preparing a management summary manual, a user's manual, a programmer's manual, and an analyst's manual.

A model summary provides a checklist which describes the model and helps make decisions on its applicablility. A bibliography with 21 references is included.

The publication was prepared for the NBS Institute for Computer Sciences and Technology by the Federal Computer Performance Evaluation and Simulation Center (FEDSIM). After thorough reviews and trial use, the document will be reissued as a Federal guideline in the FIPS (Federal Information Processing Standards) series.

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Knab, L., Mathey, R., and Jenkins, D., Laboratory Evaluation of Nondestructive Methods to Measure Moisture in Built-Up Roofing Systems, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 131, 173 pages (Jan. 1980) Stock No 003-003-02281-1, $5.50.

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Grover, C. C., Selection and Application Guide to Police Photographic Equipment, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-23, 65 pages (Aug. 1980) Stock No. 003-003-02224-1, $3.75 prepaid.

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McCarty, R. D., Interactive Fortran IV Computer Programs for the Thermodynamic and Transport Properties of Selected Cryogens (Fluids Pack), Nat Bur. Stand. (U.S.), Tech. Note 1025, 112 pages (Oct. 1980) Stock No. 003-003-02266-7, $4.50 prepaid.

NEWS BRIEFS

NBS AND NASA AGREE ON ANTENNA MEASUREMENTS. NBS and NASA have signed an agreement under which NBS' Electromagnetic Fields Division will support NASA in measuring the performance of antenna systems used for communication in outer space. Areas of possible support include near-field measurements, development of methods for measuring earth-terminal and satellite parameters, and further development and implementation of an Orbital Standards Platform concept.

COMMENTS INVITED ON ADCCP REVISIONS, MESSAGE FORMAT STANDARD. To harmonize Federal Information Processing Standards Publication (FIPS PUB) 71 with the proposed Federal Telecommunication Standard 1003, revisions in FIPS PUB 71 (Advanced Data Communication Control Procedures) have been drafted and comments are invited. Contact Eric L. Scace, National Bureau of Standards, Washington, DC 20234, 301/921-3723. NBS also requests comments on the draft technical specifications for an electronic message format standard. Review copies of the draft specs are obtainable from the NBS Standards Administration Office, Institute for Computer Sciences and Technology.

PULSE SAMPLING REDUCES POWER IN OSCILLATOR SENSORS. A simple tunnel diode oscillator circuit ban be made into a sensitive transducer that can be used over a wide temperature range for a variety of sensor applications (temperature, pressure, etc.). In low temperature applications, however, the power dissipation from the unit causes noticeable self-heating. An NBS researcher has demonstrated that such sensors can be sampled with pulses as short as 1/30 of a second, thus spreading the energy dissipation over a relatively long time, with only a minor loss in precision. In addition to the tunnel diode applications at low temperatures, results suggest the possibility of scanning many sensors with a single measurement system.

URSI GENERAL ASSEMBLY TO CONVENE IN AUGUST 1981. Over 1000 scientists from all parts of the world are expected to attend the Twentieth General Assembly of the International Union of Radio Science (URSI), to be held at the Hyatt Regency Hotel, Washington, DC, August 10-19, 1981. URSI is one of the 18 international unions within the International Council of Scientific Unions and is devoted to stimulating and coordinating international studies in the electromagnetic and telecommunication sciences. The General Assembly is the outstanding international event in the triennial program cycle of the Union. Participation is no longer restricted to official delegations of member committees; interested scientists are invited to participate in General Assembly technical programs. For further information, contact R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418, 202/389-6478.

IMPROVED TIME DOMAIN CALIBRATIONS. For the first time, NBS scientists are able to remove the effects of measurement instruments when calibrating electrical pulse generators and low-pass filters. The technique, called deconvolution, involves physical modeling and mathematical analysis procedures developed by NBS scientists and guest workers from the University of Toledo and the Centre National d'Etudes des Telecommunication (CNET), Lannion, France. The customer now receives the complete deconvoluted waveform measurement at no increase in cost.

NEXT MONTH IN

DIMENSIONS NBS

Organic compounds such as hydrocarbons are important contributors to air and water pollution. Find out how NBS is using the techniques of radiocarbon dating to trace the sources of carbon-based pollutants in the next issue of DIMENSIONS/NBS.

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